US009080688B2

(12) **United States Patent**
Satou

(10) **Patent No.: US 9,080,688 B2**
(45) **Date of Patent: Jul. 14, 2015**

(54) **FLOW REVERSING VALVE AND HEAT PUMP DEVICE USING SAME**

(75) Inventor: **Masaya Satou**, Tokyo (JP)

(73) Assignee: **Fujikoki Corporation**, Tokyo (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 1149 days.

(21) Appl. No.: **13/069,024**

(22) Filed: **Mar. 22, 2011**

(65) **Prior Publication Data**

US 2011/0232320 A1 Sep. 29, 2011

(30) **Foreign Application Priority Data**

Mar. 24, 2010 (JP) 2010-068093

(51) **Int. Cl.**

F16K 31/12	(2006.01)
F16K 11/074	(2006.01)
F16B 13/04	(2006.01)
F16K 31/124	(2006.01)
F16K 11/044	(2006.01)
F16K 31/04	(2006.01)
F16K 31/05	(2006.01)
F16K 15/18	(2006.01)

(52) **U.S. Cl.**

CPC ***F16K 31/124*** (2013.01); ***F16K 11/044*** (2013.01); *F16K 15/186* (2013.01); *F16K 31/041* (2013.01); *F16K 31/055* (2013.01)

(58) **Field of Classification Search**

CPC F16K 31/055; F16K 15/186; F16K 31/041

USPC 137/625.43, 625.63, 625.6; 62/324.6; 251/41, 30.01, 30.02, 30.04, 30.05

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

6,869,060	B2 *	3/2005	Barber et al.	251/30.02
7,621,211	B2 *	11/2009	Ma et al.	91/446
2004/0060308	A1 *	4/2004	Yoshizawa et al.	62/160

FOREIGN PATENT DOCUMENTS

JP	03-288071	* 12/1991
JP	06-235467	8/1994
JP	2006-071148	3/2006

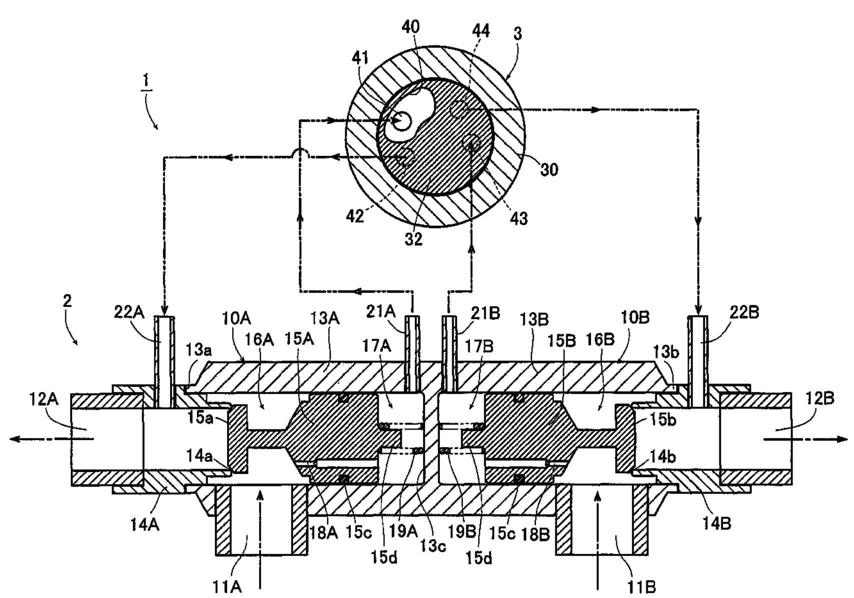
* cited by examiner

Primary Examiner — Frantz Jules
Assistant Examiner — Steve Tanenbaum
(74) *Attorney, Agent, or Firm* — McCarter & English

(57) **ABSTRACT**

A flow reversing valve includes a reversing valve main body adapted to assume a first circulatory state where a first main valve part is in a fully-open state and a second main valve part is in a fully-closed state and a second circulatory state where the first main valve part is in a fully-closed state and the second main valve part is in a fully-open state; and a flow regulating valve adapted to regulate the pressures of the respective back pressure chambers and of the first main valve part and the second main valve part. The flow regulating valve places the reversing valve main body in the first circulatory state by gradually reducing the pressure of the back pressure chamber of the first main valve part, and in the second circulatory state by gradually reducing the pressure of the back pressure chamber of the second main valve part.

11 Claims, 12 Drawing Sheets



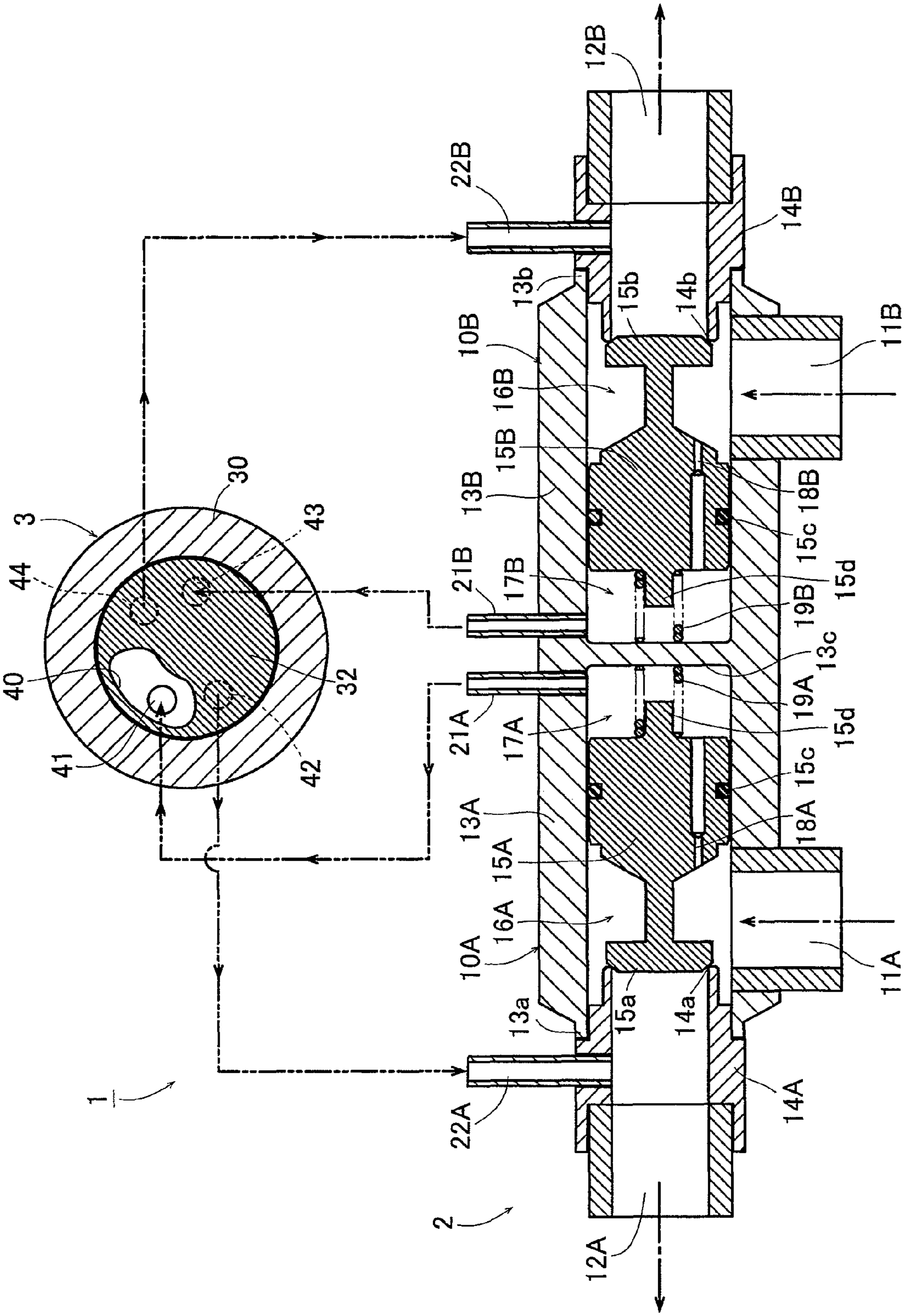

1
2
3
30
32
40
41
42
43
44
10A
10B
11A
11B
12A
12B
13A
13B
13a
13b
13c
14A
14B
14a
14b
15A
15B
15a
15b
15c
15d
16A
16B
17A
17B
18A
18B
19A
19B
21A
21B
22A
22B

FIG. 1

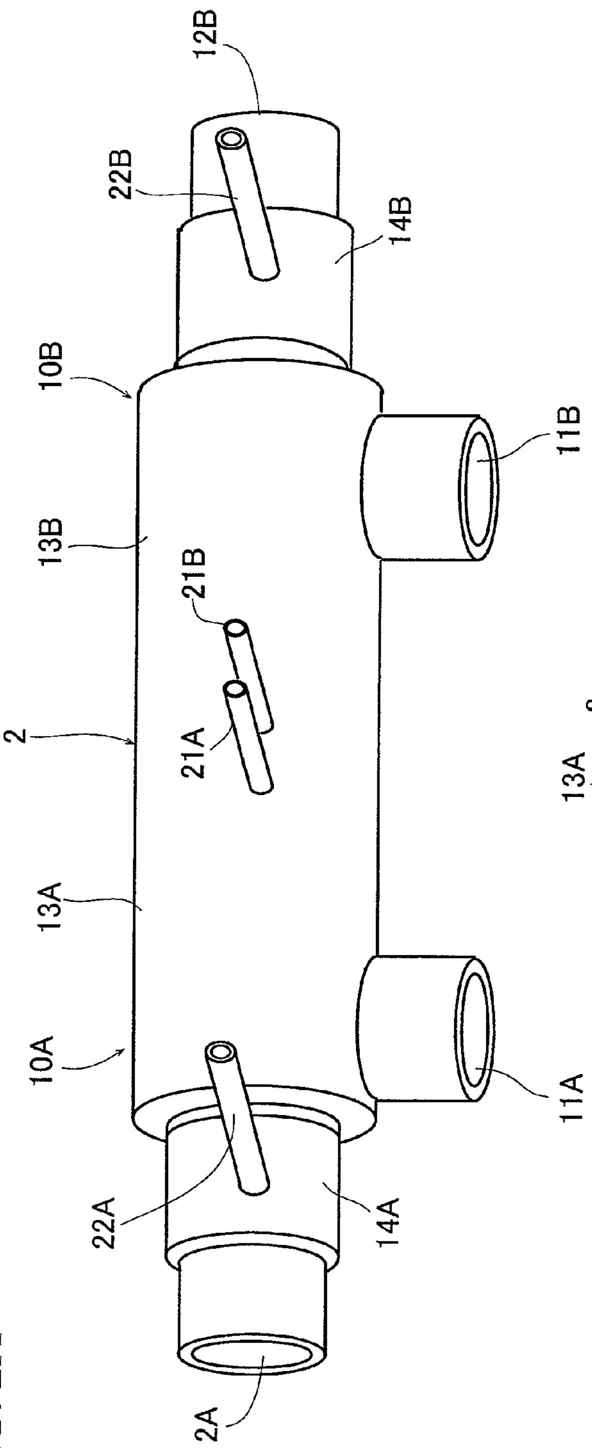

12B
22B
14B
10B
11B
13B
21B
2
21A
13A
10A
11A
22A
14A
12A

FIG. 2A

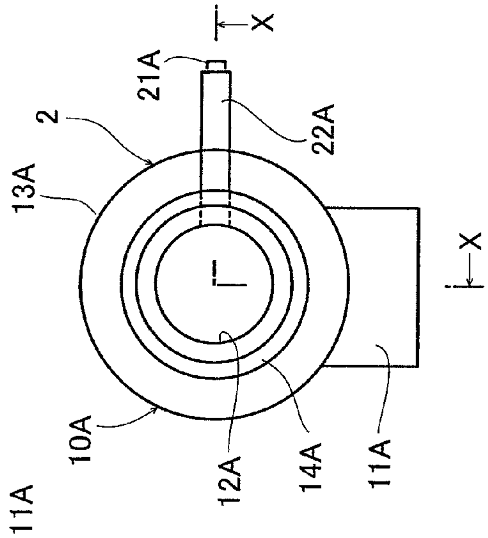

X
21A
2
22A
13A
X
10A
12A
14A
11A

FIG. 2B

FIG. 3A

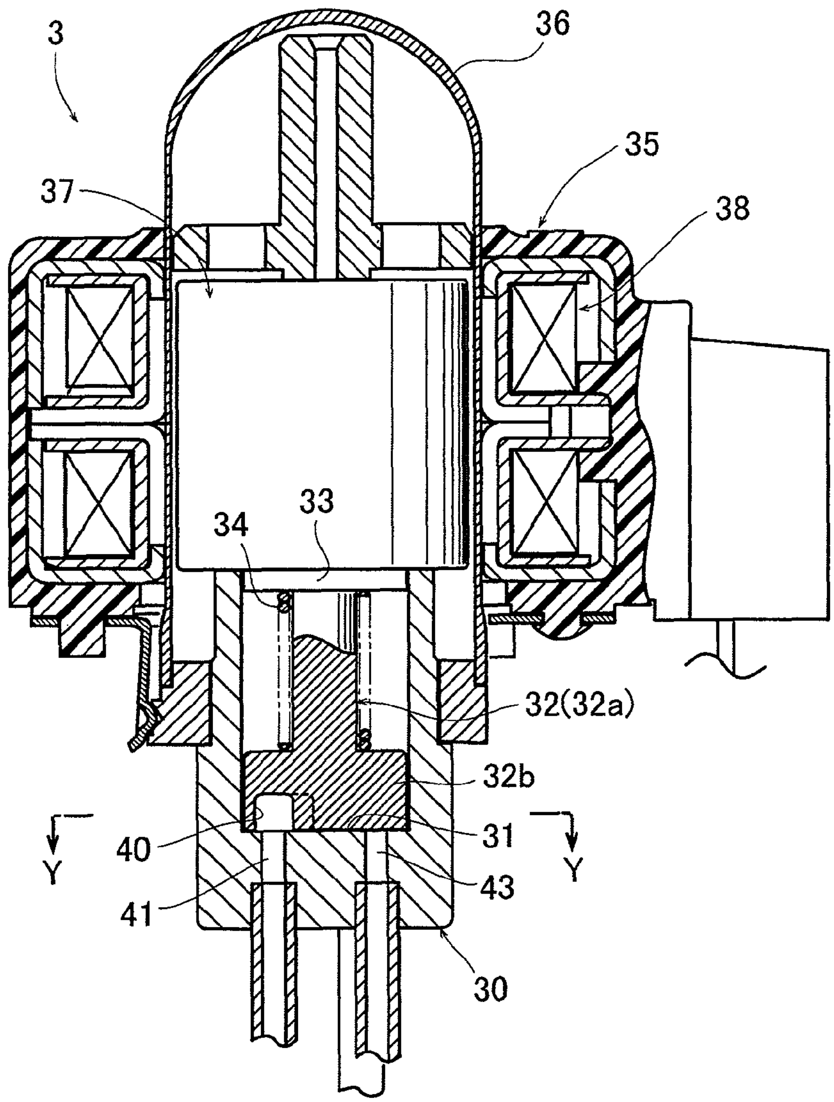


FIG. 3B

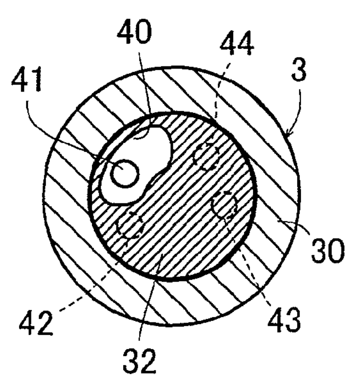


FIG. 4A

< During cooling operation >

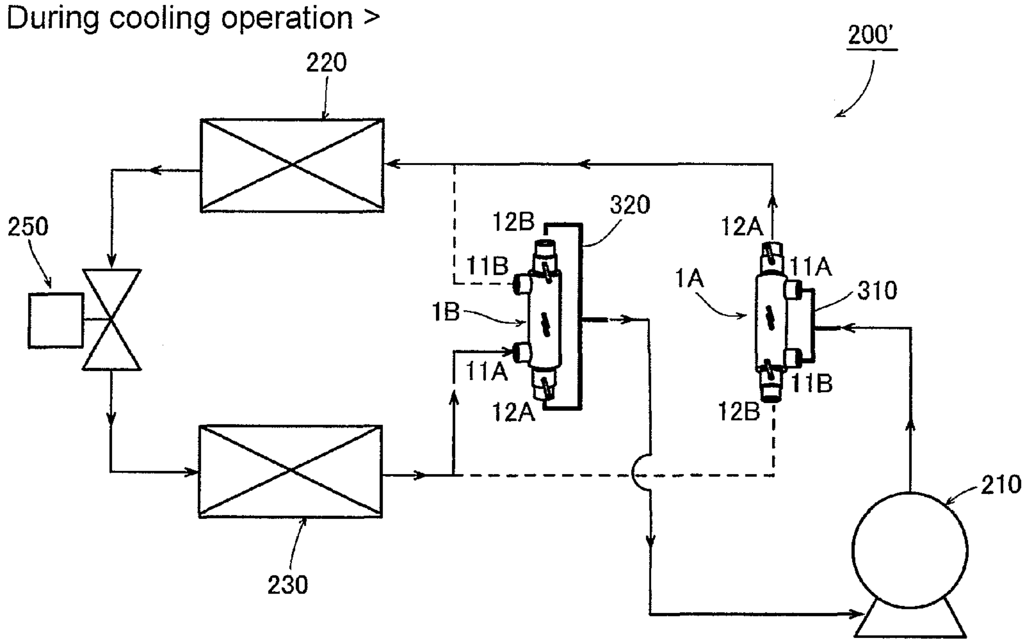
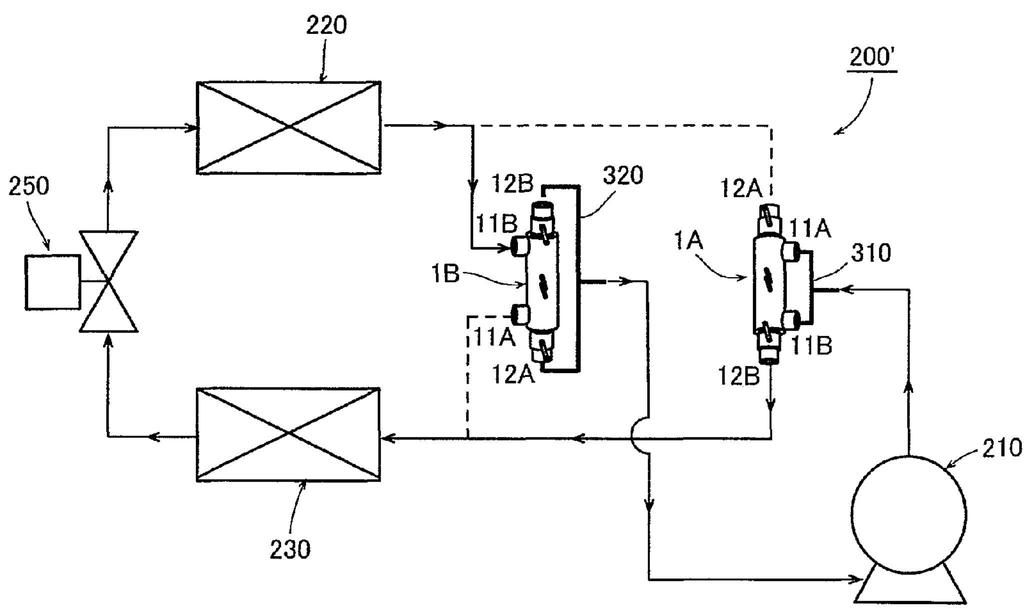


FIG. 4B

< During heating operation >



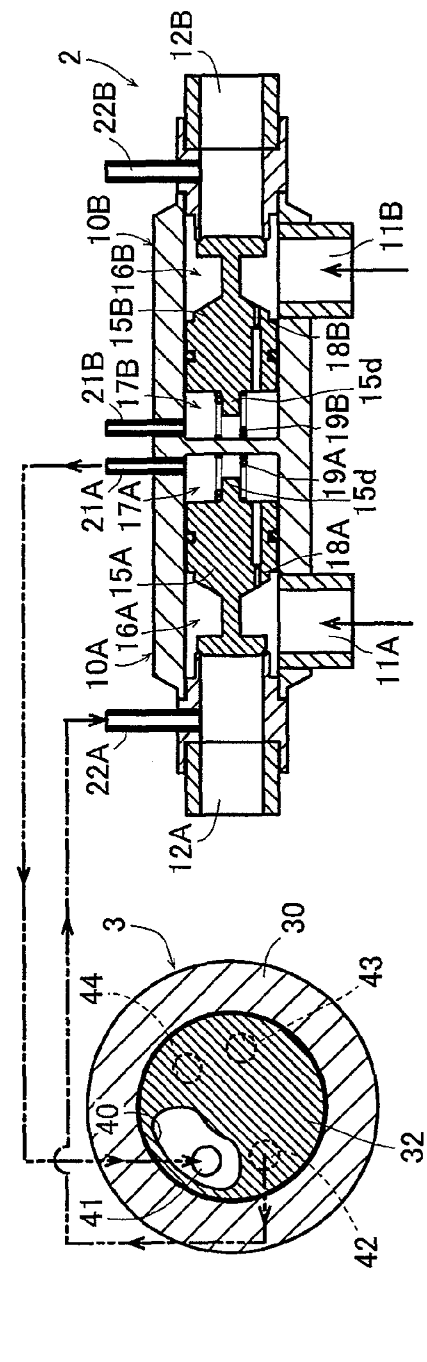

2
12B
22B
10B
11B
16B
15B
21B
17B
18B
15d
19B
19A
21A
17A
15A
16A
18A
10A
11A
22A
12A
3
30
44
43
40
32
41
42

FIG. 5A

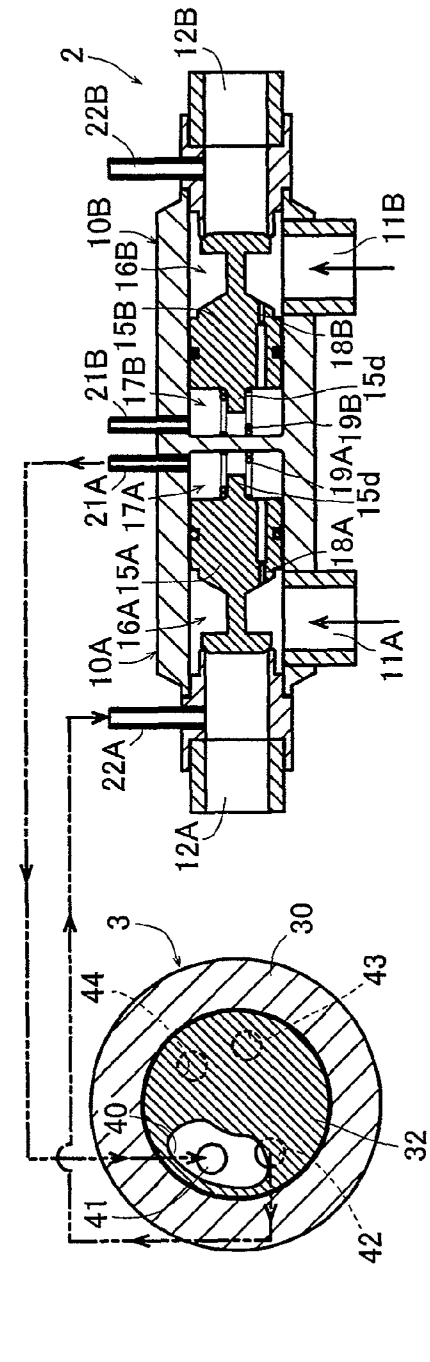

2
12B
22B
10B
11B
16B
15B
21B
17B
18B
15d
19B
19A
21A
17A
15A
16A
18A
10A
11A
22A
12A
3
30
44
43
40
32
41
42

FIG. 5B

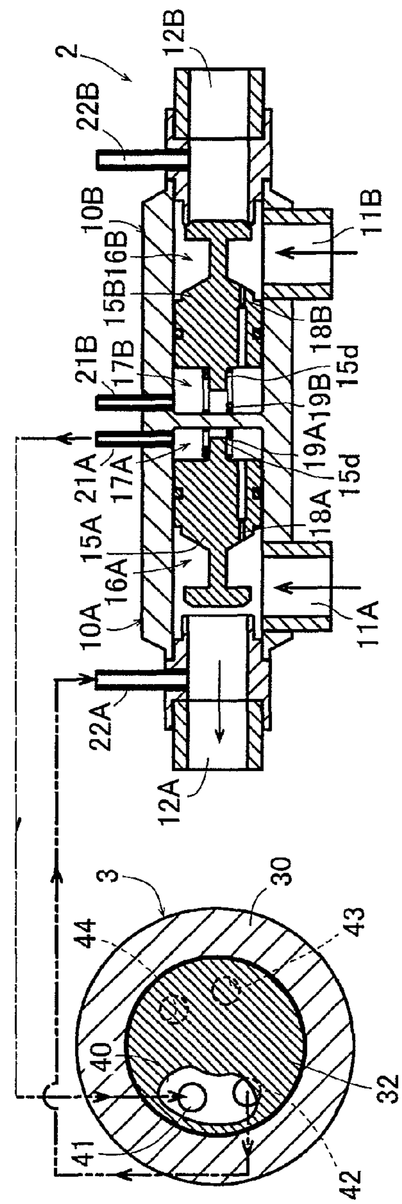

2
12B
22B
10B
11B
15B
16B
21B
17B
18B
19B
15d
21A
17A
19A
15d
15A
16A
18A
10A
11A
22A
12A
3
30
44
43
40
32
41
42

FIG. 5C

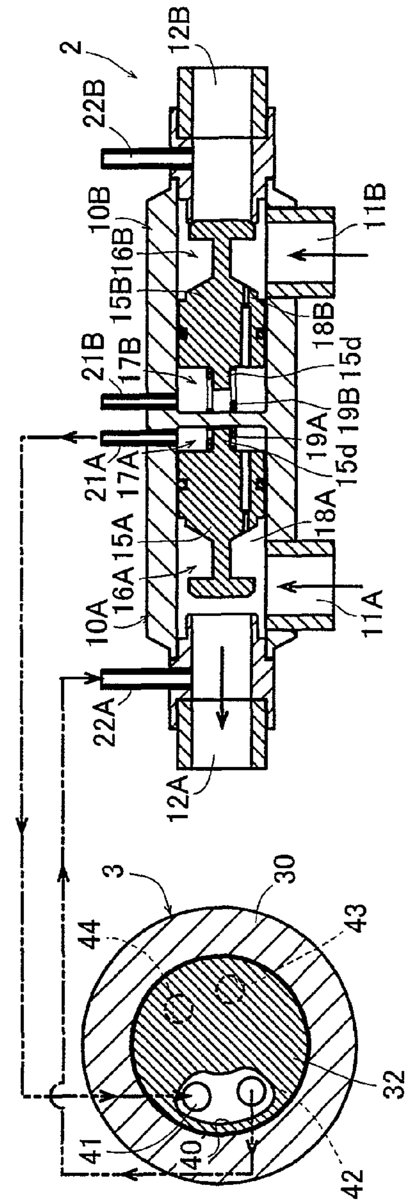

2
12B
22B
10B
11B
15B
16B
21B
17B
18B
15d
19B
21A
17A
19A
15d
15A
16A
18A
10A
11A
22A
12A
3
30
44
43
32
41
40
42

FIG. 5D

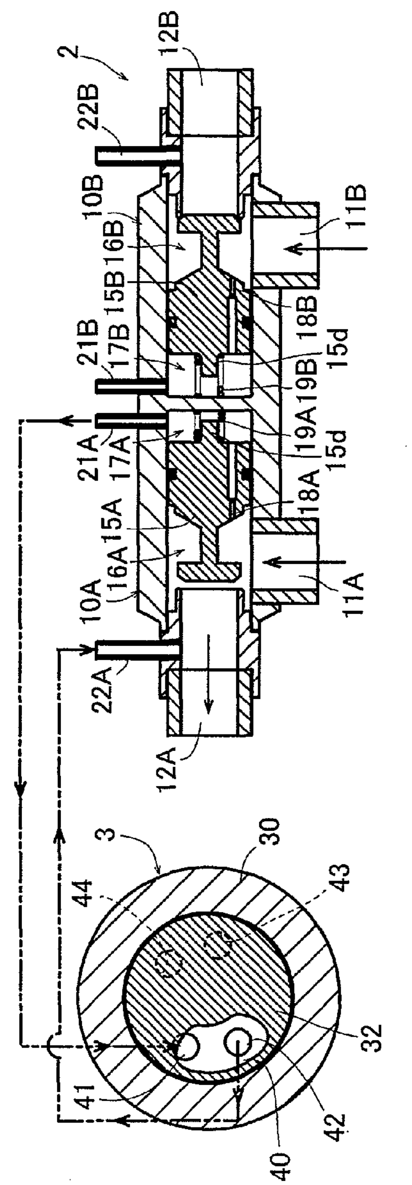

2
12B
22B
10B
16B
15B
21B
17B
11B
18B
19B
15d
19A
21A
17A
15d
18A
15A
16A
10A
11A
22A
12A
3
30
44
43
32
41
40
42

FIG. 6A

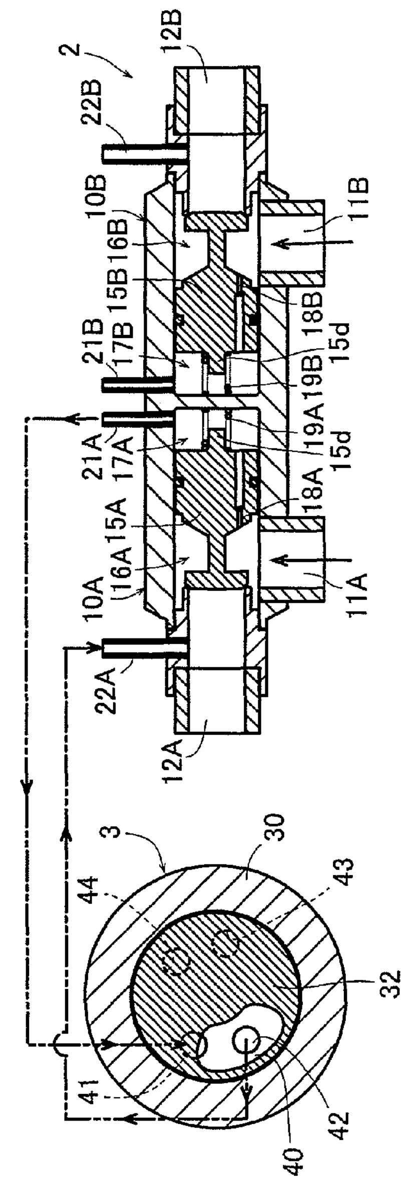

2
12B
22B
10B
16B
15B
21B
17B
11B
18B
19B
15d
19A
21A
17A
15d
18A
15A
16A
10A
11A
22A
12A
3
30
44
43
32
41
40
42

FIG. 6B

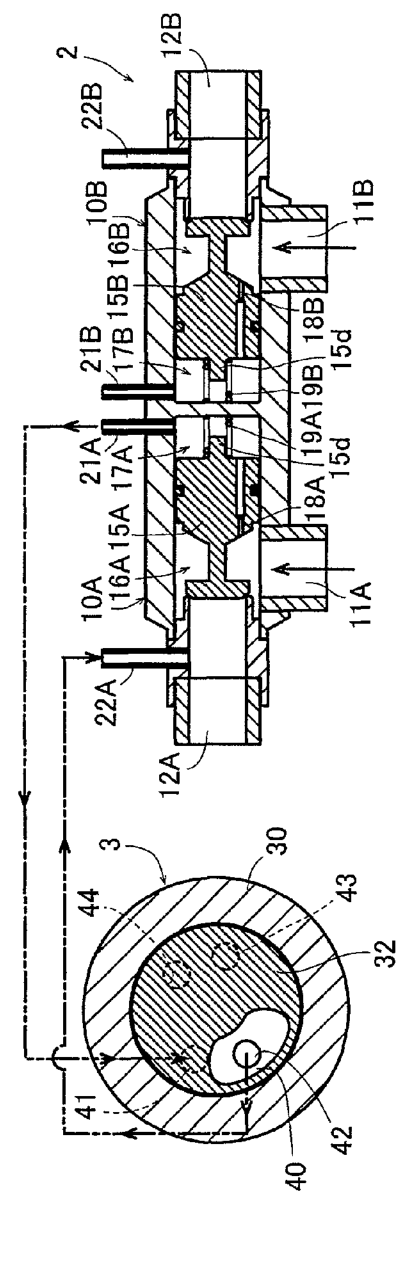

2
22B
12B
10B
16B
15B
21B
17B
18B
15d
19B
19A
21A
17A
15d
18A
15A
16A
10A
11B
11A
22A
12A
3
30
44
43
32
41
40
42

FIG. 6C

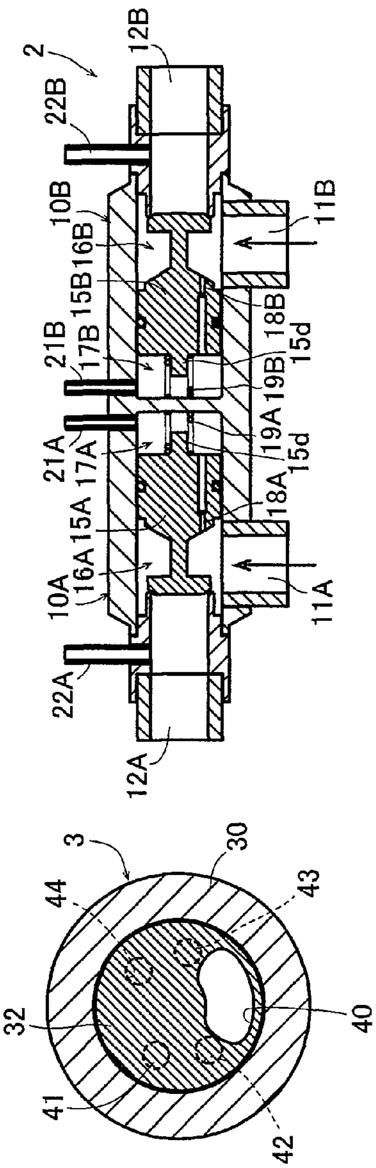

2
22B
12B
10B
16B
15B
21B
17B
18B
15d
19B
19A
21A
17A
15d
18A
15A
16A
10A
11B
11A
22A
12A
3
30
44
43
32
40
41
42

FIG. 6D

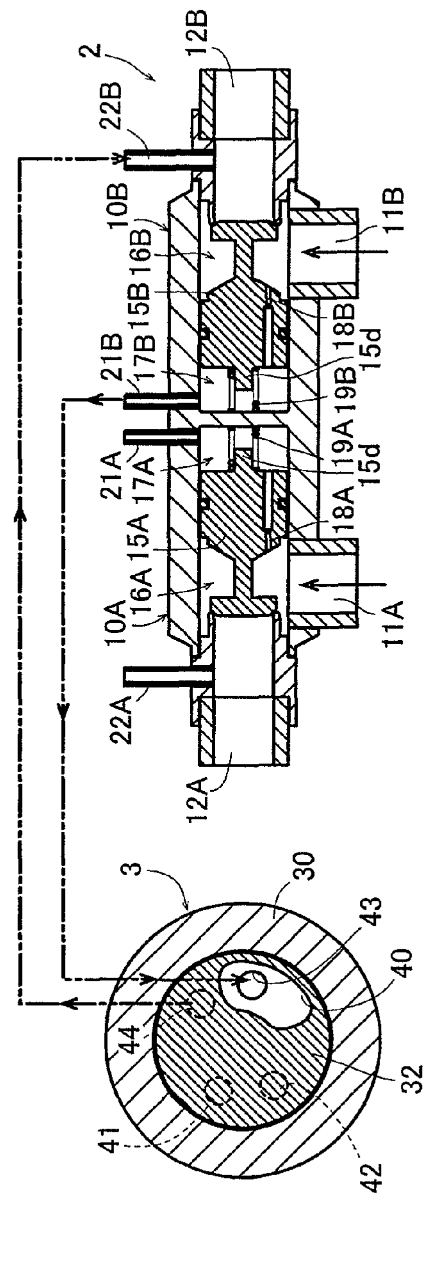

2
12B
22B
10B
11B
16B
15B
17B
21B
18B
15d
19B
19A
21A
17A
15A
16A
10A
18A
11A
22A
12A
3
30
43
40
44
32
41
42

FIG. 7A

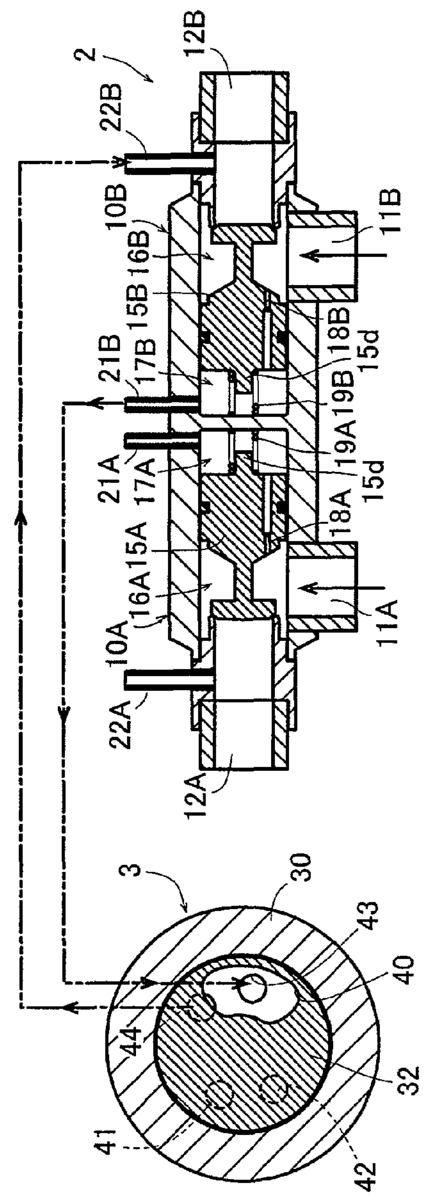
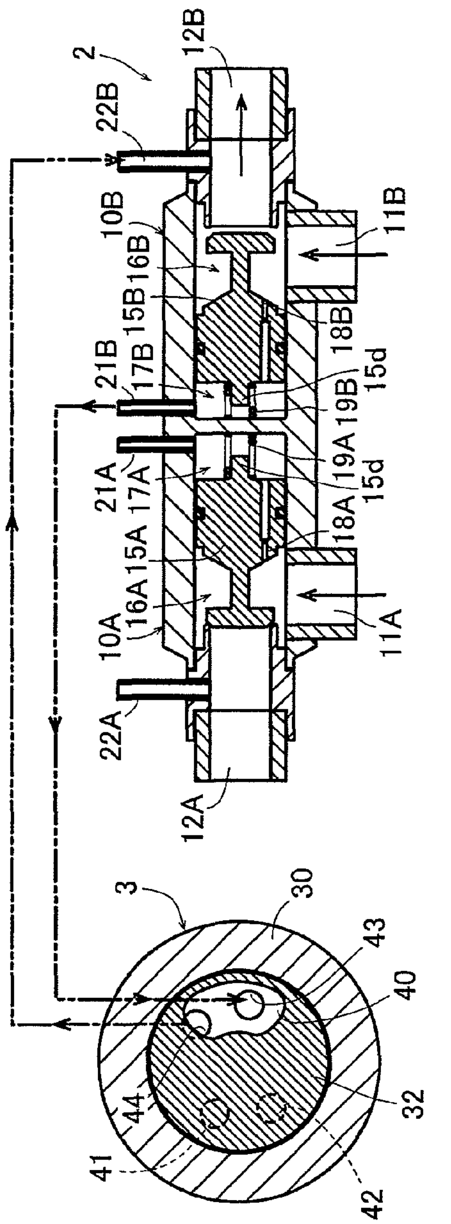
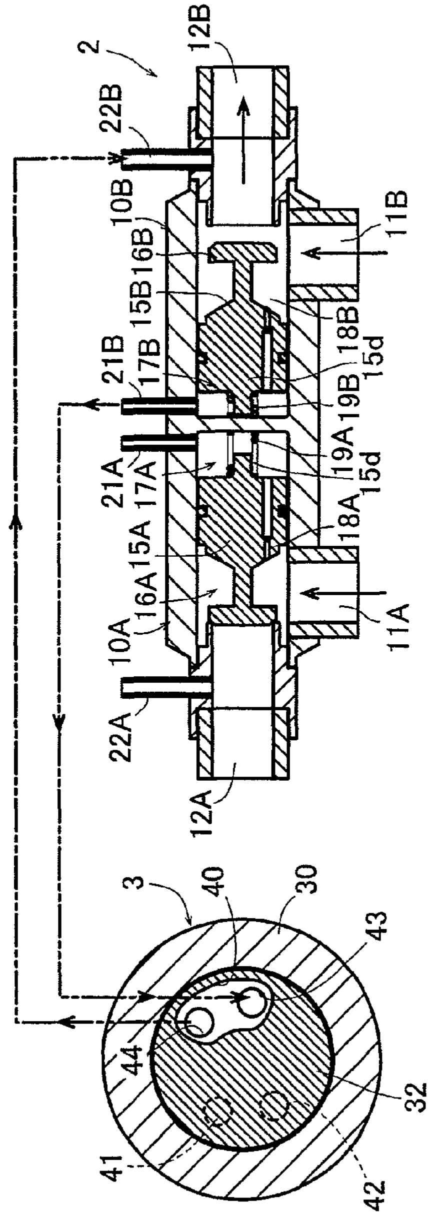

2
12B
22B
10B
11B
16B
15B
17B
21B
18B
15d
19B
19A
21A
17A
15A
16A
10A
18A
11A
22A
12A
3
30
43
40
44
32
41
42

FIG. 7B



2
22B
12B
10B
11B
16B
15B
21B
17B
18B
19B
15d
21A
17A
19A
15d
18A
15A
16A
10A
11A
22A
12A
3
30
43
40
44
32
41
42

FIG. 7C



2
22B
12B
10B
11B
16B
15B
21B
17B
18B
19B
15d
21A
17A
19A
15d
18A
15A
16A
10A
11A
22A
12A
3
40
30
43
44
32
41
42

FIG. 7D

FIG. 8

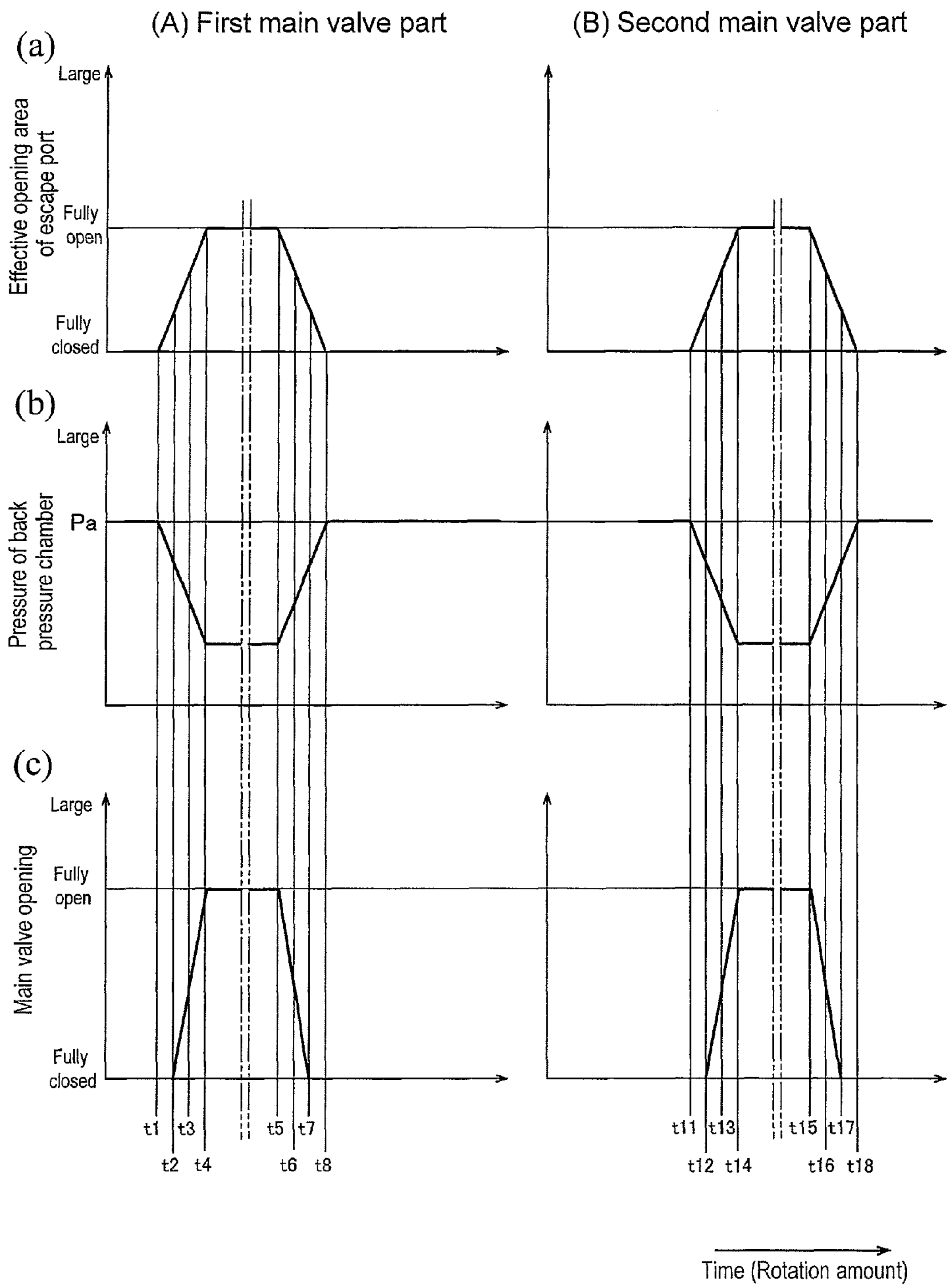

(A) First main valve part
(B) Second main valve part
(a)
Large
Effective opening area of escape port
Fully open
Fully closed
(b)
Large
Pressure of back pressure chamber
Pa
(c)
Large
Main valve opening
Fully open
Fully closed
t1 t3 t5 t7
t2 t4 t6 t8
t11 t13 t15 t17
t12 t14 t16 t18
Time (Rotation amount)

FIG. 9A

< During cooling operation >

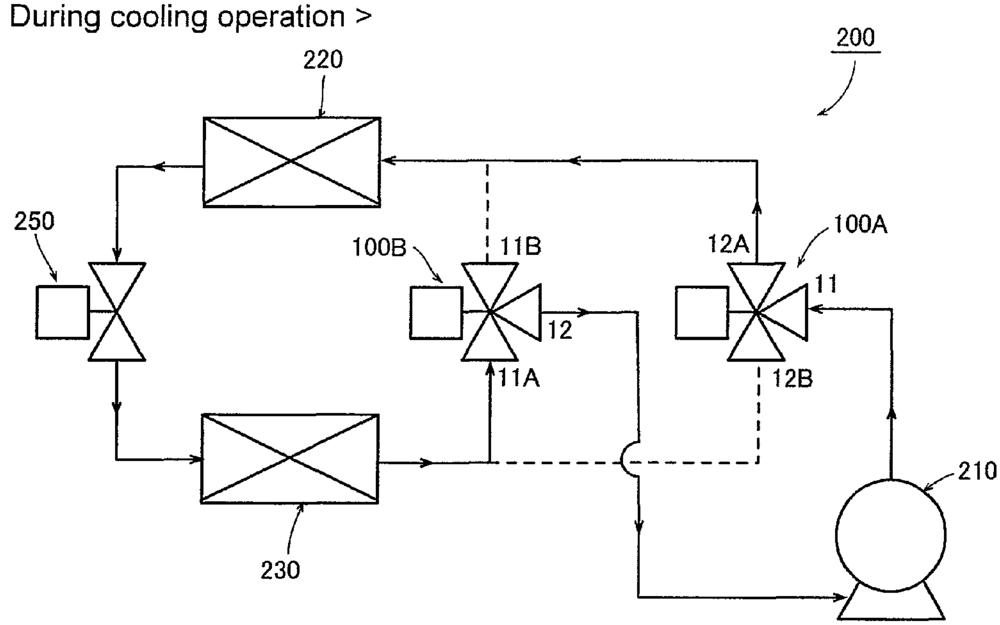
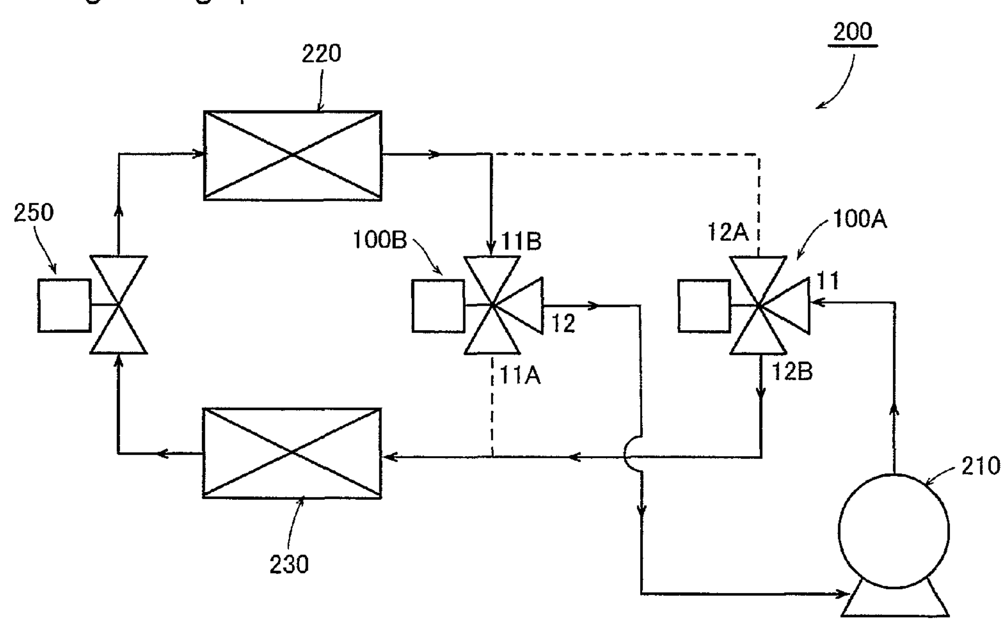


FIG. 9B

< During heating operation >



FLOW REVERSING VALVE AND HEAT PUMP DEVICE USING SAME

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims priority to Japanese Patent Application No. 2010-068093, filed Mar. 24, 2010, all of which is herein incorporated by reference in its entirety.

FIELD OF THE INVENTION

The present invention relates to a flow reversing valve, such as a three-way reversing valve, etc., that changes the flow direction of a fluid, and to a heat pump device using same.

BACKGROUND OF THE INVENTION

Heat pump devices (air conditioners, etc.) generally comprise a four-way reversing valve as a flow path (flow direction) reversing means in addition to a compressor, a vapor-liquid separator, a condenser (outdoor heat exchanger), an evaporator (indoor heat exchanger), an expansion valve, etc. (see JP Patent Publication (Kokai) No. 2001-295951 A (Patent Document 1), etc.).

However, with such heat pump devices employing a four-way reversing valve, since a high-temperature and high-pressure refrigerant and a low-temperature and low-pressure refrigerant flow in close proximity to each other within the four-way reversing valve, there is a problem in that the amount of heat transferred (heat transfer amount) from the high-temperature and high-pressure refrigerant to the low-temperature and low-pressure refrigerant becomes greater, thereby causing non-negligible heat loss and a drop in thermal efficiency.

SUMMARY OF THE INVENTION

The present inventors have contemplated having the flow reversing function of the four-way reversing valve provided by way of two three-way reversing valves instead. A schematic cycle example of such a heat pump device employing two three-way reversing valves is shown in FIGS. **9**A and **9**B. The heat pump device **200** in the illustrated example comprises a compressor **210**, a vapor-liquid separator (not shown), a condenser (outdoor heat exchanger) **220**, an evaporator (indoor heat exchanger) **230**, an expansion valve **250**, etc. Further, a first three-way reversing valve **100**A is disposed between the discharge side of the compressor **210** and the condenser **220**, and a second three-way reversing valve **100**B is disposed between the evaporator **230** and the suction side of the compressor **210**.

The first three-way reversing valve **100**A comprises one inlet **11** and two outlets **12**A and **12**B, and is so arranged as to be capable of assuming a first A circulatory state, in which the inlet **11** and the outlet **12**A are connected while the inlet **11** and the outlet **12**B are disconnected, and a second A circulatory state in which the inlet **11** and the outlet **12**A are disconnected while the inlet **11** and the outlet **12**B are connected.

The second three-way reversing valve **100**B comprises two inlets **11**A and **11**B and one outlet **12**, and is so arranged as to be capable of assuming a first B circulatory state, in which the inlet **11**A and the outlet **12** are connected while the inlet **11**B and the outlet **12** are disconnected, and a second B circulatory state in which the inlet **11**A and the outlet **12** are disconnected while the inlet **11**B and the outlet **12** are connected.

With this heat pump device **200**, during cooling operation, as shown in FIG. **9**A, the first three-way reversing valve **100**A assumes the first A circulatory state, and the second three-way reversing valve **100**B assumes the first B circulatory state. Thus, the refrigerant discharged from the compressor **210** flows as follows: the inlet **11** of the first three-way reversing valve **100**A the outlet **12**A of the first three-way reversing valve **100**A→the condenser **220** the expansion valve **250**→the evaporator **230** the inlet **11**A of the second three-way reversing valve **100**B→the outlet **12** of the second three-way reversing valve **100**B→the suction side of the compressor **210**.

In contrast, during heating operation, as shown in FIG. **9**B, the first three-way reversing valve **100**A assumes the second A circulatory state, and the second three-way reversing valve **100**B assumes the second B circulatory state. Thus, the refrigerant discharged from the compressor **210** flows as follows: the inlet **11** of the first three-way reversing valve **100**A→the outlet **12**B of the first three-way reversing valve **100**A→the evaporator **230**→the expansion valve **250**→the condenser **220**→the inlet **11**B of the second three-way reversing valve **100**B→the outlet **12** of the second three-way reversing valve **100**B→the suction side of the compressor **210**.

In general, the flow reversing valves, such as conventional three-way reversing valves, etc., employed in the above-mentioned conventional heat pump device, etc., are ordinarily of an electromagnetic type (i.e., a type in which a plunger valve member is attracted by a solenoid). Thus, the reversing (opening/closing) operation is extremely fast, lasting only a few hundred milliseconds, and there is a possibility that, due to the speed of the reversing operation thereof, flood backs (a phenomenon where the refrigerant is returned to the compressor, etc., while still partially in liquid form), impact sounds, etc., might occur, causing system failures in extreme cases.

In addition, with electromagnetic valves, since it is necessary to continue applying a current even after the flow has been reversed, there are such problems as greater power consumption, etc.

The present invention is made in view of the circumstances above, and an object thereof is to provide a flow reversing valve, such as a three-way reversing valve, etc., that is capable of gently performing a reversing operation, of effectively suppressing occurrences of flood backs, impact sounds, etc., and of reducing power consumption relative to electromagnetic valves, as well as to provide a heat pump device using same.

In order to achieve the object above, one flow reversing valve according to the present invention basically comprises: a reversing valve main body comprising a first main valve part and a second main valve part, each of which is configured as a two-way valve, the reversing valve main body being so arranged as to be capable of assuming a first circulatory state, where the first main valve part is in a fully open state and the second main valve part is in a fully closed state, and a second circulatory state, where the first main valve part is in a fully closed state and the second main valve part is in a fully open state; and a pressure regulating means that serves as a pilot valve for the first main valve part and the second main valve part.

Another flow reversing valve according to the present invention comprises: a reversing valve main body comprising a first main valve part and a second main valve part, each being formed with an inlet, an outlet, a valve chamber, and a back pressure chamber, the reversing valve main body being so arranged as to be capable of assuming a first circulatory state, where the first main valve part is in a fully open state and the second main valve part is in a fully closed state, and a second circulatory state, where the first main valve part is in a fully closed state and the second main valve part is in a fully open state; and back pressure regulating means configured to regulate the respective pressures of the back pressure chambers of the first main valve part and the second main valve part, wherein the back pressure regulating means is so arranged as to cause the reversing valve main body to assume the first circulatory state by gradually reducing the pressure of the back pressure chamber of the first main valve part, and to assume the second circulatory state by gradually reducing the pressure of the back pressure chamber of the second main valve part.

Preferably, the first main valve part and the second main valve part each comprise a tubular main valve case with a base. The main valve case is provided with a main valve seat having a main valve opening, and a main valve member that opens/closes the main valve opening is fitted in the main valve case in a freely slidable manner. A main valve chamber is formed between the main valve seat and the main valve member, an inlet that opens into the main valve chamber is formed, and an outlet is formed downstream of the main valve opening. A back pressure chamber is formed between a base part of the main valve case and the main valve member, and a pressure equalizing hole that places the main valve chamber and the back pressure chamber in communication with each other is provided in the main valve member.

In this case, a valve closing spring that constantly biases the main valve member in the valve closing direction is preferably disposed in the respective back pressure chambers of the first main valve part and the second main valve part.

The back pressure regulating means preferably comprises a single flow regulating valve or two flow regulating valves that is/are capable of regulating the respective amounts of fluid to be released to the outlet from the back pressure chambers of the first main valve part and the second main valve part.

On the other hand, a heat pump device according to the present invention comprises: a compressor; a condenser; an evaporator; and an expansion valve, wherein a first flow reversing valve of the structure above is disposed between the discharge side of the compressor and the condenser, and a second flow reversing valve of the structure above is disposed between the evaporator and the suction side of the compressor.

In this case, in a more preferable embodiment, with respect to the first flow reversing valve, the inlet of the first main valve part and the inlet of the second main valve part are both connected to the discharge side of the compressor, and one of the outlet of the first main valve part and the outlet of the second main valve part is connected to the condenser while the other is connected to the evaporator. With respect to the second flow reversing valve, one of the inlet of the first main valve part and the inlet of the second main valve part is connected to the condenser while the other is connected to the evaporator, and the outlet of the first main valve part and the outlet of the second main valve part are both connected to the suction side of the compressor.

In a preferred embodiment of a flow reversing valve according to the present invention, the first circulatory state is assumed by reducing the pressure of the back pressure chamber of the first main valve part, and the second circulatory state is assumed by reducing the pressure of the back pressure chamber of the second main valve part. Thus, with respect to the first main valve part and the second main valve part, the transition from a fully closed state to a fully open state and the transition from a fully open state to a fully closed state (main valve opening/closing operation), as well as the switch from the first circulatory state to the second circulatory state and the switch from the second circulatory state to the first circulatory state (flow reversing operation) can all be performed gently. As a result, it is possible to effectively suppress occurrences of flood backs, impact sounds, etc., and to thereby prevent system failures, etc., with respect to heat pump devices, etc., that employ the flow reversing valve above.

In addition, since there is no need to apply, after flow reversal, a current to the back pressure regulating means comprising the flow regulating valve(s), etc., it is possible to reduce power consumption relative to those of an electromagnetic type.

Further, since the back pressure regulating means comprising the flow regulating valve(s), etc., is so arranged as to serve as a pilot valve with respect to both main valve parts, flow reversal can be carried out with a smaller driving force as compared to those of the conventional electromagnetic type, it is possible to reduce energy consumption, such as power consumption, etc., from this point as well.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic configuration diagram showing one embodiment of a flow reversing valve according to the present invention.

FIG. **2**A is an external perspective view of the reversing valve main body shown in FIG. **1**, and FIG. **2**B is a side view of the reversing valve main body shown in FIG. **2**A as seen from the left.

FIG. **3**A is a partially cutaway sectional view of the flow regulating valve shown in FIG. **1**, and FIG. **3**B is a sectional view taken along and as viewed in the direction of arrows Y-Y in FIG. **3**A.

FIGS. **4**A and **4**B are diagrams showing schematic cycle examples of a heat pump device employing the flow reversing valve shown in FIG. **1**.

FIGS. **5**A through **5**D are diagrams illustrating the operation of the flow reversing valve shown in FIG. **1**.

FIGS. **6**A through **6**D are diagrams illustrating the operation of the flow reversing valve shown in FIG. **1**.

FIGS. **7**A through **7**D are diagrams illustrating the operation of the flow reversing valve shown in FIG. **1**.

FIGS. **8**A through **8**C are timing diagrams illustrating the operation of the flow reversing valve shown in FIG. **1**.

FIGS. **9**A and **9**B are diagrams showing schematic cycle examples of a heat pump device employing two three-way reversing valves.

DESCRIPTION OF FIGURE ELEMENTS

1 (**1**A, **1**B) Flow reversing valve (three-way reversing valve)
2 Reversing valve main body
3 Flow regulating valve
10A, **10**B Main valve part
11A, **11**B Inlet
12A, **12**B Outlet
13A, **13**B Main valve case
14A, **14**B Main valve seat
15A, **15**B Main valve member
16A, **16**B Main valve chamber
17A, **17**B Back pressure chamber
18A, **18**B Pressure equalizing hole
19A, **19**B Valve closing spring
21A, **21**B Escape port
22A, **22**B Discharge port
30 Valve housing

32 Rotary valve member
35 Stepping motor
37 Rotor
38 Stator
40 Communicating channel
41 First port
42 Second port
43 Third port
44 Fourth port
200, **200'** Heat pump device
210 Compressor
220 Condenser
230 Evaporator
250 Expansion valve

DETAILED DESCRIPTION OF THE INVENTION

Embodiments of a flow reversing valve of the present invention are described below with reference to the drawings.

FIG. **1** is a schematic configuration diagram showing one embodiment of a flow reversing valve according to the present invention. The flow reversing valve **1** shown in the diagram comprises a reversing valve main body **2** and a flow regulating valve **3**. FIG. **2**A is an external perspective view of the reversing valve main body **2** shown in FIG. **1**, and FIG. **2**B is a side view of the reversing valve main body **2** shown in FIG. **2**A as viewed from the left. FIG. **3**A is a partially cut-away sectional view of the flow regulating valve **3** shown in FIG. **1**, and FIG. **3**B is a sectional view taken along and as viewed in the direction of arrows Y-Y in FIG. **3**A. It is noted that the reversing valve main body **2** portion of FIG. **1** is a sectional view taken along and as viewed in the direction of arrows X-X in FIG. **2**B, and the flow regulating valve **3** portion of FIG. **1** is identical to FIG. **3**B.

The flow reversing valve **1** of the present embodiment has been developed for use as a three-way reversing valve in a heat pump device such as that shown in FIGS. **9**A and **9**B mentioned above (details will be discussed later with reference to FIGS. **4**A and **4**B). It basically comprises: the reversing valve main body **2** comprising a first main valve part **10**A and a second main valve part **10**B which are arranged symmetrically on the left and right and configured as two-way valves; and the flow regulating valve **3** of an electric motor type (rotary type), which serves as a pilot valve (back pressure regulating means) with respect to the first main valve part **10**A and the second main valve part **10**B.

The first main valve part **10**A and the second main valve part **10**B of the reversing valve main body **2** respectively comprise cylindrical main valve cases **13**A and **13**B each having a base. The main valve cases **13**A and **13**B are integrated back to back so as to share a base part **13***c*, and their tip parts **13***a* and **13***b* are open. Main valve seats **14**A and **14**B that respectively have main valve openings **14***a* and **14***b* are respectively provided at the tip parts **13***a* and **13***b* of the main valve cases **13**A and **13**B. Main valve members **15**A and **15**B that respectively have poppet parts **15***a* and **15***b* for opening/closing the respective main valve openings **14***a* and **14***b* are fitted within the respective main valve cases **13**A and **13**B in a freely slidable manner. Seal materials **15***c* and **15***c* for suppressing or sealing leaks are provided on the outer circumferences of the main valve members **15**A and **15**B. Further, a protruding stopper **15***d* for restricting the fully open position is provided at the rear end face of each of the main valve members **15**A and **15**B.

Main valve chambers **16**A and **16**B are respectively formed between the main valve seats **14**A and **14**B (main valve openings **14***a* and **14***b*) and the main valve members **15**A and **15**B of the respective main valve cases **13**A and **13**B. Inlets **11**A and **11**B, through which a fluid, such as a refrigerant, etc., is introduced, open into the respective main valve chambers **16**A and **16**B. Outlets **12**A and **12**B through which the fluid is led out are respectively formed downstream of the main valve openings **14***a* and **14***b*.

Further, back pressure chambers **17**A and **17**B are respectively formed between the base part **13***c* and the main valve members **15**A and **15**B of the respective main valve cases **13**A and **13**B. Pressure equalizing holes **18**A and **18**B that respectively communicate the main valve chambers **16**A and **16**B with the back pressure chambers **17**A and **17**B are formed in the respective main valve members **15**A and **15**B. Further, valve closing springs **19**A and **19**B comprising compression coil springs that constantly bias the respective main valve members **15**A and **15**B in the valve closing direction are provided, in a compressed manner, between the respective main valve members **15**A and **15**B and the base part **13***c* within the back pressure chambers **17**A and **17**B.

The reversing valve main body **2** thus constructed is capable of assuming a first circulatory state, where the first main valve part **10**A is placed in a fully open state by moving the main valve member **15**A away from the main valve seat **14**A and the second main valve part **10**B is placed in a fully closed state by seating the main valve member **15**B in the main valve seat **14**B, and a second circulatory state, where the first main valve part **10**A is placed in a fully closed state by seating the main valve member **15**A in the main valve seat **14**A and the second main valve part **10**B is placed in a fully open state by moving the main valve member **15**B away from the main valve seat **14**B.

In the first circulatory state, the inlet **11**A and the outlet **12**A of the first main valve part **10**A are in communication with each other, while the path between the inlet **11**B and the outlet **12**B of the second main valve part **10**B is blocked. In the second circulatory state, the path between the inlet **11**A and the outlet **12**A of the first main valve part **10**A is blocked, while the inlet **11**B and the outlet **12**B of the second main valve part **10**B are in communication with each other.

On the other hand, the flow reversing valve **1** of the present embodiment comprises a back pressure regulating means that regulates the pressure of each of the back pressure chambers **17**A and **17**B of the respective first main valve part **10**A and the second main valve part **10**B.

The back pressure regulating means comprises: escape ports **21**A and **21**B respectively provided in the back pressure chambers **17**A and **17**B; discharge ports **22**A and **22**B respectively provided in the main valve seats **14**A and **14**B (downstream of the main valve openings **14***a* and **14***b*); and the flow regulating valve **3**.

As shown in FIG. **3**A, the flow regulating valve **3** comprises: a tubular valve housing **30** with a base and having a valve seat part **31**; a can **36** whose lower end part is sealingly joined with the valve housing **30**; a stepping motor **35** comprising a rotor **37** disposed on the inner circumferential side of the can **36** and a stator **38** that is externally fitted and fixed on the outer circumference of the can **36**; and a rotary valve member **32** of an inverted T-shaped cross-section, which is rotated by this stepping motor **35**.

With respect to the rotary valve member **32**, a vertical part **32***a* thereof is rotatably supported by a guide member **33** that is affixed to the upper portion of the valve housing **30**, and the lower end face thereof is pressed strongly against the valve seat part **31** by way of the biasing force of a compression coil spring **34** disposed between a lower part **32***b* of the rotary valve member **32** and the guide member **33**.

There are provided in the valve seat part **31** and such that they lie on the circumference of the same circle: a first port **41** and a second port **42** to which the escape port **21**A and the discharge port **22**A provided in the first main valve part **10**A are to be connected, respectively; and a third port **43** and a fourth port **44** to which the escape port **21**B and the discharge port **22**B provided in the second main valve part **10**B are to be connected, respectively. By way of example, the positional relationship among the ports may be such that the second port **42** is provided at an anti-clockwise angular interval of approximately 60 degrees relative to the first port **41**, the third port **43** is provided at an anti-clockwise angular interval of approximately 140 degrees relative to the second port **42**, the fourth port **44** is provided at an anti-clockwise angular interval of approximately 60 degrees relative to the third port **43**, and the angular interval between the fourth port **44** and the first port **41** is approximately 100 degrees.

Further, in the lower half part of the lower part **32***b* of the valve member **32** is provided a communicating channel **40** for selectively placing the first port **41** and the second port **42** or the third port **43** and the fourth port **44** in communication with each other, the communicating channel **40** having an open lower face and being of a fan-shape with rounded corners in planar view (the central angle being approximately 90 degrees).

The flow regulating valve **3** thus structured is so arranged as to rotate the rotary valve member **32** relatively slowly by regulating the excitation speed of the stator **38**, for example. It is noted that for such purposes as reducing the rotation speed of the rotary valve member **32** or obtaining a high torque, it is possible to employ, besides the above, such methods as installing a gear reduction mechanism between the rotor **37** and the rotary valve member **32**, and so forth.

Next, the operation of the flow reversing valve **1** thus structured will be described with reference to FIGS. **5**A-**5**D through FIGS. **7**A-**7**D and to the timing diagrams in FIG. **8**.

As shown in FIG. **5**A, in a state where the rotary valve member **32** only opens the first port **41**, that is, in a state where none of the first port **41** and the second port **42**, as well as the third port **43** and the fourth port **44**, are in communication with one another, the refrigerant in the respective back pressure chambers **17**A and **17**B of the first main valve part **10**A and the second main valve part **10**B is not discharged. Thus, for both main valve parts **10**A and **10**B, the forces acting on the main valve members **15**A and **15**B in the valve closing direction (i.e., the pressures of the back pressure chambers **17**A and **17**B+the biasing forces of the valve closing springs **19**A and **19**B) are greater than the forces acting in the valve opening direction (i.e., pressures Pa of the main valve chambers **16**A and **16**B). In other words, because the refrigerant is, via the pressure equalizing holes **18**A and **18**B, gradually introduced into the respective back pressure chambers **17**A and **17**B of both main valve parts **10**A and **10**B from the valve chambers **16**A and **16**B, the pressures of the back pressure chambers **17**A and **17**B become approximately equal to pressures Pa of the valve chambers **16**A and **16**B, the main valve members **15**A and **15**B are pressed against the respective main valve seats **14**A and **14**B due to the biasing forces of the valve closing springs **19**A and **19**B, and both the first main valve part **10**A and the second main valve part **10**B are placed in a fully closed state. This state corresponds to the state before time t**1** in FIG. **8**, that is, a state where the effective opening areas of the escape ports **21**A and **21**B are 0, the pressures of the back pressure chambers **17**A and **17**B are equal to pressures Pa of the valve chambers **16**A and **16**B, and the opening in both main valve parts **10**A and **10**B is 0.

As the rotary valve member **32** is rotated anti-clockwise from the state shown in FIG. **5**A and the second port **42** is slightly opened as shown in FIG. **5**B, the first port **41** and the second port **42** are placed in communication with each other via the communicating channel **40**. At this point, the opening area of the second port **42** becomes the effective opening area of the escape port **21**A. Thus, the refrigerant within the back pressure chamber **17**A flows as follows and the pressure of the back pressure chamber **17**A drops slightly: escape port **21**A→**22** first port **41**→communicating channel **40**→second port **42**→discharge port **22**A→outlet **12**A. However, since, at this point, the force acting in the valve closing direction is still greater than the force acting in the valve opening direction, the first main valve part **10**A remains in a fully closed state. This period between FIGS. **5**A and **5**B corresponds to the period between times t**1** and t**2** in FIG. **8**.

As the rotary valve member **32** is further rotated anti-clockwise from the state shown in FIG. **5**B and the second port **42** is opened by about ⅔ as shown in FIG. **5**C, the pressure of the back pressure chamber **17**A drops further. As a result, the main valve member **15**A moves to the right and is slightly separated from the main valve seat **14**A, the first main valve part **10**A is placed in a half open state, and the refrigerant flows out from the inlet **11**A to the outlet **12**A while being throttled to some extent. This period between FIGS. **5**B and **5**C corresponds to the period between times t**2** and t**3** in FIG. **8**.

As the rotary valve member **32** is further rotated anti-clockwise from the state shown in FIG. **5**C and the second port **42** is fully opened as shown in FIG. **5**D, the pressure of the back pressure chamber **17**A drops further. As a result, the main valve member **15**A moves further to the right and is significantly separated from the main valve seat **14**A, the protruding stopper **15***d* protruding from the rear end face thereof abuts the base part **13***c*, and the first main valve part **10**A is placed in a fully open state. Thus, the flow reversing valve **1** is placed in the first circulatory state, and the refrigerant flows from the inlet **11**A to the outlet **12**A with virtually no throttling. This period between FIGS. **5**C and **5**D corresponds to the period between times t**3** and t**4** in FIG. **8**.

Here, at a point when the first circulatory state, in which the first main valve part **10**A is in a fully open state and the second main valve part **10**B is in a fully closed state, is entered as shown in FIG. **5**D, if the application of a current to the stator **38** of the motor **35** is stopped, the rotation of the rotary valve member **32** stops, the rotary valve member **32** keeps the position shown in FIG. **5**D (i.e., the fully open position for the ports **41** and **42**), and the flow reversing valve **1** maintains the first circulatory state. This period of the first circulatory state corresponds to the period between times t**4** and t**5** in FIG. **8**.

Next, as the rotary valve member **32** is further rotated anti-clockwise from the state shown in FIG. **5**D and the first port **41** is slightly closed as shown in FIG. **6**A, the amount of refrigerant that is released from the back pressure chamber **17**A decreases. As a result, the pressure of the back pressure chamber **17**A increases to some extent due to the refrigerant introduced from the pressure equalizing hole **18**A, the main valve member **15**A moves slightly to the left, and the first main valve part **10**A is placed in a half open state. This period between FIG. **5**D and FIG. **6**A corresponds to the period between times t**5** and t**6** in FIG. **8**.

As the rotary valve member **32** is further rotated anti-clockwise from the state shown in FIG. **6**A and the first port **41** is closed by about ⅔ as shown in FIG. **6**B, the amount of refrigerant that is released from the back pressure chamber **17**A decreases further. As a result, the pressure of the back pressure chamber **17**A increases due to the refrigerant introduced from the pressure equalizing hole **18**A, the main valve member **15**A moves further to the left, the main valve member **15**A is seated in the main valve seat **14**A, and the first main valve part **10**A is placed in a fully closed state. This period between FIGS. **6**A and **6**B corresponds to the period between times t**6** and t**7** in FIG. **8**.

As the rotary valve member **32** is further rotated anti-clockwise from the state shown in FIG. **6**B and the first port **41** is fully closed as shown in FIG. **6**C, there is created a state in which, as in the state shown in FIG. **5**A, none of the first port **41** and the second port **42**, as well as the third port **43** and the fourth port **44**, are in communication with one another, the main valve member **15**A is pressed against the main valve seat **14**A due to the biasing force of the valve closing spring **19**A, and the first main valve part **10**A and the second main valve part **10**B are both placed in a fully closed state. This period between FIGS. **6**B and **6**C corresponds to the period between times t**7** and t**8** in FIG. **8**.

As the rotary valve member **32** is further rotated anti-clockwise from the state shown in FIG. **6**C and all of the ports **41**, **42**, **43** and **44** are closed as shown in FIG. **6**D, the first main valve part **10**A and the second main valve part **10**B both maintain their fully closed states.

Here, at a point when both main valve parts **10**A and **10**B have entered a fully closed state as shown in FIG. **6**C or **6**D, if the application of a current to the stator **38** of the motor **35** is stopped, the rotation of the rotary valve member **32** stops, the rotary valve member **32** keeps the position shown in FIG. **6**C or **6**D, and the flow reversing valve **1** maintains a state in which both main valve parts **10**A and **10**B are fully closed. This period corresponds to the period after time t**8** in FIG. **8**.

Next, as the rotary valve member **32** is further rotated anti-clockwise from the state shown in FIG. **6**D, the second main valve part **10**B, as shown in FIGS. **7**A, **7**B and **7**C, transitions from a fully closed state to a half open state and then to a fully open state as in the first main valve part **10**A shown in FIGS. **5**A to **5**C mentioned above. As the second main valve part **10**B is placed in a fully open state as shown in FIG. **7**D, the flow reversing valve **1** enters the second circulatory state. This period between FIGS. **7**A and **7**D corresponds to the period between times t**11** and t**14** in FIG. **8**.

Further, as the rotary valve member **32** is further rotated anti-clockwise from the state shown in FIG. **7**D, the second main valve part **10**B transitions from a fully open state to a half open state and then to a fully closed state as in the first main valve part **10**A shown in FIGS. **6**A to **6**D mentioned above. This operation of the second main valve part **10**B is similar to that of the first main valve part **10**A, and its description will therefore be omitted.

Thus, with the flow reversing valve **1** of the present embodiment, by regulating the excitation speed of the stator **38** of the flow regulating valve **3** (or by installing a gear reduction mechanism between the rotor **37** and the rotary valve member **32**, and so forth), the rotary valve member **32** is rotated relatively slowly. The flow reversing valve **1** is thus so arranged as to be placed in the first circulatory state by gradually reducing the pressure of the back pressure chamber **17**A of the first main valve part **10**A, and to be placed in the second circulatory state by gradually reducing the pressure of the back pressure chamber **17**B of the second main valve part **10**B. As a result, it is possible to gently perform the transitions for the first main valve part **10**A and the second main valve part **10**B from a fully closed state to a fully open state and from a fully open state to a fully closed state (main valve opening/closing operation), as well as the switches from the first circulatory state to the second circulatory state and from the second circulatory state to the first circulatory state (flow reversing operation). Accordingly, it is possible to effectively suppress occurrences of flood backs, impact sounds, etc., and to thereby prevent system failures, etc.

In addition, since there is no need to apply a current to the flow regulating valve **3** once the rotary valve member **32** has been placed in a certain position, such as after flow reversal, etc., it is possible to reduce power consumption relative to valves of an electromagnetic type.

Further, since the flow regulating valve **3** is so arranged as to serve as a pilot valve for both main valve parts **10**A and **10**B, flow reversal can be performed with a smaller driving force as compared to conventional valves of an electromagnetic type. Accordingly, it is possible to reduce energy consumption, such as power consumption, etc., from this point as well.

It is noted that the flow reversing operation speed and the main valve opening/closing operation speed may be adjusted in accordance with the specifications of the heat pump system, etc., in which this flow reversing valve is to be employed.

In addition, in the embodiment above, a single rotary four-port flow regulating valve **3** is used as a back pressure regulating means. However, a four-port flow regulating valve of a kind other than a rotary valve may be used, or two two-port flow regulating vales, etc., may be used in its place. Further, as a back pressure regulating means, two two-way valves (ON/OFF valves), etc., may be used in place of the flow regulating valve so as to only perform the flow reversing operation, or the main valve opening/closing operation, gently.

Further, with respect to the flow revering valve **1** of the embodiment above, two inlets and two outlets are provided. However, if the present flow reversing valve **1** is to be used as a three-way reversing valve, the inlets **11**A and **11**B may be combined into one inlet using a tee fitting, etc., or the outlets **12**A and **12**B may be combined into one outlet using a tee fitting, etc., for example.

Next, an example will be described with reference to FIGS. **4**A and **4**B where the flow reversing valve **1** in the embodiment above is used as three-way reversing valves (**100**A and **100**B) in the heat pump device **200** shown in FIG. **9** previously discussed.

In the heat pump device **200'** in the illustrated example, a first flow reversing valve **1**A of the same structure as the embodiment above is disposed between the discharge side of the compressor **210** and the condenser **220**, and a second flow reversing valve **1**B of the same structure as the embodiment above is disposed between the evaporator **230** and the suction side of the compressor **210**.

More specifically, with respect to the first flow reversing valve **1**A, the inlet **11**A of the first main valve part **10**A and the inlet **11**B of the second main valve part **10**B are each connected to the discharge side of the compressor **210** via a tee fitting **310**, etc., the outlet **12**A of the first main valve part **10**A is connected to the condenser **220**, and the outlet **12**B of the second main valve part **10**B is connected to the evaporator **230**.

On the other hand, with respect to the second flow reversing valve **1**B, the inlet **11**A of the first main valve part **10**A is connected to the evaporator **230**, the inlet **11**B of the second main valve part **10**B is connected to the condenser **220**, and the outlet **12**A of the first main valve part **10**A and the outlet **12**B of the second main valve part **10**B are each connected to the suction side of the compressor **210** via a tee fitting **320**, etc.

With the heat pump device **200'** above, by controlling the flow regulating valve, during cooling operation, as shown in FIG. **4**A, the first flow reversing valve **1**A assumes the first circulatory state, and the second flow reversing valve **1**B also assumes the first circulatory state. The refrigerant discharged from the compressor **210** thus flows as follows: the inlet **11**A of the first flow reversing valve **1**A→the outlet **12**A of the first flow reversing valve **1**A→the condenser **220** the expansion valve **250**→the evaporator **230**→the inlet **11**A of the second flow reversing valve **1**B→the outlet **12**A of the second flow reversing valve **1**B→the suction side of the compressor **210**.

In contrast, during heating operation, as shown in FIG. **4**B, the first flow reversing valve **1**A assumes the second circulatory state, and the second flow reversing valve **1**B also assumes the second circulatory state. The refrigerant discharged from the compressor **210** thus flows as follows: the inlet **11**B of the first flow reversing valve **1**A→the outlet **12**B of the first flow reversing valve **1**A→the evaporator **230**→the expansion valve **250**→the condenser **220**→the inlet **11**B of the second flow reversing valve **1**B→the outlet **12**B of the second flow reversing valve **1**B→the suction side of the compressor **210**.

It is thus possible to have the flow reversing function of a four-way reversing valve provided by using two of the flow reversing valves **1** of the embodiment above in a heat pump device.

Although the systems and methods of the present disclosure have been described with reference to exemplary embodiments thereof, the present disclosure is not limited to such exemplary embodiments and/or implementations. Rather, the systems and methods of the present disclosure are susceptible to many implementations and applications, as will be readily apparent to persons skilled in the art from the disclosure hereof. The present disclosure expressly encompasses such modifications, enhancements and/or variations of the disclosed embodiments. Since many changes could be made in the above construction and many widely different embodiments of this disclosure could be made without departing from the scope thereof, it is intended that all matter contained in the drawings and specification shall be interpreted as illustrative and not in a limiting sense. Additional modifications, changes, and substitutions are intended in the foregoing disclosure. Accordingly, it is appropriate that the appended claims be construed broadly and in a manner consistent with the scope of the disclosure.

What is claimed is:

1. A flow reversing valve, comprising:

a reversing valve main body including:

a first main valve part and a second main valve part in each of which an inlet, an outlet, a main valve chamber, and a back pressure chamber are formed;

a first main valve member that is fitted in a freely slidable manner between the main valve chamber and the back pressure chamber of the first main valve part;

a second main valve member that is fitted in a freely slidable manner between the main valve chamber and the back pressure chamber of the second main valve part; and

a pressure equalizing hole that is formed in each of the first main valve member and the second main valve member to communicate the main valve chamber with the back pressure chamber, the reversing valve main body being adapted to be capable of assuming a first circulatory state in which the first main valve part is in a fully open state and the second main valve part is in a fully closed state, and a second circulatory state in which the first main valve part is in a fully closed state and the second main valve part is in a fully open state; and

back pressure regulating means adapted to regulate the pressure of each of the back pressure chambers of the first main valve part and the second main valve part;

wherein the back pressure regulating means is adapted to regulate the pressure of the back pressure chamber by an amount of fluid between the back pressure chamber and the outlet so as to place the reversing valve main body in the first circulatory state by reducing the pressure of the back pressure chamber of the first main valve part, and in the second circulatory state by reducing the pressure of the back pressure chamber of the second main valve part; and

wherein the back pressure chambers of the first and second main valve parts are arranged symmetrically on opposing sides of and are separated by a shared base.

2. The flow reversing valve of claim **1**, wherein:

each of the first main valve part and the second main valve part further comprises a tubular main valve case with a base;

in each of the main valve cases, a main valve seat having a main valve opening is provided and the first main valve member and the second main valve member adapted to open/close the main valve opening are fitted in a freely slidable manner,

between the main valve seat and the first and second main valve members are formed the main valve chamber and the inlet, the inlet opening into the main valve chamber;

the outlet is formed downstream of the main valve opening; and

the back pressure chamber is formed between the base of the main valve case and the first main valve member and the second main valve member.

3. The flow reversing valve of claim **2**, wherein a valve closing spring adapted to constantly bias the first main valve member and the second main valve member in a valve closing direction is disposed in each of the back pressure chambers of the first main valve part and the second main valve part.

4. The flow reversing valve of claim **1**, wherein the back pressure regulating means comprises one or two flow regulating valves that are capable of regulating the amount of fluid that is released from the back pressure chamber to the outlet in each of the first main valve part and the second valve part.

5. A heat pump device, comprising:

a compressor,

a condenser,

an evaporator,

an expansion valve, and

first and second flow reversing valves, each of the first and second flow reversing valves comprising:

a reversing valve main body including:

a first main valve part and a second main valve part in each of which an inlet, an outlet, a main valve chamber, and a back pressure chamber are formed;

a first main valve member that is fitted in a freely slidable manner between the main valve chamber and the back pressure chamber of the first main valve part;

a second main valve member that is fitted in a freely slidable manner between the main valve chamber and the back pressure chamber of the second main valve part; and

a pressure equalizing hole that is formed in each of the first main valve member and the second main valve member to communicate the main valve chamber with the back pressure chamber, the reversing valve main body being adapted to be capable of assuming a first circulatory state in which the first main valve part is in a fully open state and the second main valve part is in a fully closed state, and a second circulatory state in which the first main valve part is in a fully closed state and the second main valve part is in a fully open state; and

back pressure regulating means adapted to regulate the pressure of each of the back pressure chambers of the first main valve part and the second main valve part;

wherein the back pressure regulating means is adapted to regulate the pressure of the back pressure chamber by an amount of fluid between the back pressure chamber and the outlet so as to place the reversing valve main body in the first circulatory state by reducing the pressure of the back pressure chamber of the first main valve part, and in the second circulatory state by reducing the pressure of the back pressure chamber of the second main valve part;

wherein the back pressure chambers of the first and second main valve parts are arranged symmetrically on opposing sides of and are separated by a shared base;

wherein the first flow reversing valve is disposed between a discharge side of the compressor and the condenser; and

wherein the second flow reversing valve is disposed between the evaporator and a suction side of the compressor.

6. The heat pump device of claim **5**, wherein:

with respect to the first flow reversing valve, the inlet of the first main valve part and the inlet of the second main valve part are each connected to the discharge side of the compressor, and one of the outlet of the first main valve part and the outlet of the second main valve part is connected to the condenser while the other is connected to the evaporator; and

with respect to the second flow reversing valve, one of the inlet of the first main valve part and the inlet of the second main valve part is connected to the condenser while the other is connected to the evaporator, and the outlet of the first main valve part and the outlet of the second main valve part are each connected to the suction side of the compressor.

7. A reversing valve main body, comprising:

a first main valve part and a second main valve part in each of which an inlet, an outlet, a main valve chamber, and a back pressure chamber are formed,

wherein:

each of the first main valve part and the second main valve part comprise a tubular main valve case with a base,

in each of the tubular main valve cases a main valve seat having a main valve opening is provided,

the inlet opening into the main valve chamber is formed, and

the outlet is formed downstream of the main valve opening,

a first main valve member that is fitted in a freely slidable manner between the main valve chamber and the back pressure chamber of the first main valve part; and

a second main valve member that is fitted in a freely slidable manner between the main valve chamber and the back pressure chamber of the second main valve part;

wherein the reversing valve main body is adapted to be capable of assuming a first circulatory state in which the first main valve part is in a fully open state and the second main valve part is in a fully closed state, and a second circulatory state in which the first main valve part is in a fully closed state and the second main valve part is in a fully open state by the first main valve member and the second main valve member; and

wherein the back pressure chambers of the first and second main valve parts are arranged symmetrically on opposing sides of and are separated by a shared base.

8. A heat pump device, comprising:

a compressor,

a condenser,

an evaporator,

an expansion valve, and

first and second flow reversing valves, each of the first and second flow reversing valves comprising a reversing valve main body which includes:

a first main valve part and a second main valve part in each of which an inlet, an outlet, a main valve chamber, and a back pressure chamber are formed,

wherein:

each of the first main valve part and the second main valve part comprise a tubular main valve case with a base,

in each of the tubular main valve cases a main valve seat having a main valve opening is provided,

the inlet opening into the main valve chamber is formed, and

the outlet is formed downstream of the main valve opening,

a first main valve member that is fitted in a freely slidable manner between the main valve chamber and the back pressure chamber of the first main valve part; and

a second main valve member that is fitted in a freely slidable manner between the main valve chamber and the back pressure chamber of the second main valve part;

wherein the reversing valve main body is adapted to be capable of assuming a first circulatory state in which the first main valve part is in a fully open state and the second main valve part is in a fully closed state, and a second circulatory state in which the first main valve part is in a fully closed state and the second main valve part is in a fully open state by the first main valve member and the second main valve member;

wherein the back pressure chambers of the first and second main valve parts are arranged symmetrically on opposing sides of and are separated by a shared base;

wherein the first flow reversing valve is disposed between a discharge side of the compressor and the condenser; and

wherein the second flow reversing valve is disposed between the evaporator and a suction side of the compressor.

9. The flow reversing valve of claim **1**, wherein the first main valve member and the second main valve member are arranged symmetrically on opposing sides of the shared base.

10. The reversing valve main body of claim **7**, wherein the tubular main valve cases of the first and second main valve parts are arranged symmetrically on opposing sides of the shared base, the shared base being shared by the tubular main valve cases of the first and second main valve parts.

11. The reversing valve main body of claim **10**, wherein the tubular main valve cases of the first and second main valve parts are integrated back-to-back to share the shared base.

* * * * *